N87-16432

COMMERCIAL MODULE TEST PROGRAM

JET PROPULSION LABORATORY

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Purpose

- Investigate state of the art of module design and manufacture
- Identify problems requiring additional research

Approach

- Obtain commercial PV modules in current production
- Perform Block V Qualification Tests
- Perform failure analysis
- Obtain modules with defects corrected
- Repeat qualification tests

Module Manufacturers

AEG Telefunken	West Germany
Helios	Italy
Photowatt	France
Hoxan	Japan
Kyocera	Japan
Siemens	West Germany
Solavolt	USA
Solec	USA
Toyomenka	Japan

Efficiency Comparisons

Module Manufacturer	Power, Module (W)	Efficiency, Module (%)	Efficiency, Encapsulated Cell (%)	Efficiency, Module, at 0.9 Packing Factor (%)
Single-XTL Cells				
Helios	41.7	9.4	11.6	10.4
Hoxan	37.5	9.3	13.9	12.5
Siemens	130.8	8.7	11.6	10.4
Toyomenka	40.3	10.5	11.7	10.5
Semi-XTL Cells				
AEG Telefunken	38.7	7.9	9.8	8.8
Photowatt	36 1	7.5	10.0	9.0
Kyocera	42.8	9.8	12.0	10.8
Solavolt	38.6	8.4	10.6	9.5
Solec	40.3	10.5	11.7	10.5

The above data are based on JPL power measurements of one sample of the type module obtained for qualification testing and on nominal dimensions of module and cell areas.

Module Description
Manufacturer: Helios, Italy

Mechanical

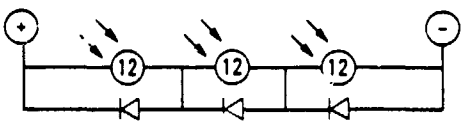
Dimensions
Module: 131 cm x 34.0 cm
Cell: 10.0 cm^2

Packing factor: 0.81

Materials
Cells: Single XTL Silicon
Superstrate: Tempered glass
Encapsulant: EVA
Back cover: Tedlar
Edge seal: Silicon rubber
Frame: Aluminum

Electrical

CIRCUIT



Sample Performance (Standard Conditions)

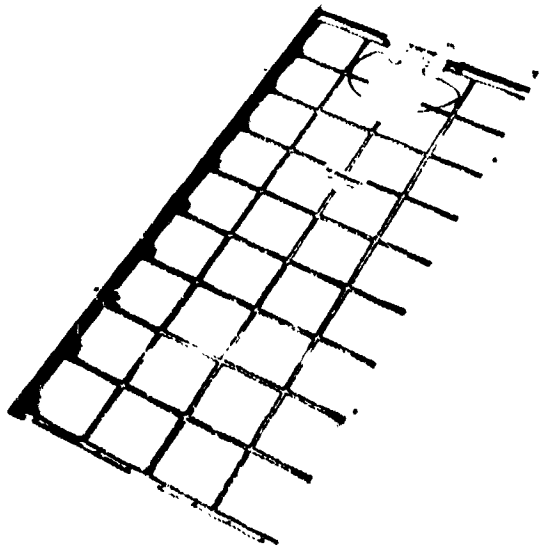
Power, max:	41.7 W
Voltage:	15.8 V
Current:	2.64 A
V_{oc}:	20.2 V
I_{sc}:	3.02 A
η, module:	9.4%
η, encapsulated cell:	11.6%

Photovoltaic Module (Top View)
Manufacturer: Helios, Italy

Photovoltaic Module (Bottom View)
Manufacturer: Helios, Italy

Photovoltaic Module (Top View)
Manufacturer: Photowatt, France

Photovoltaic Module (Bottom View)
Manufacturer: Photowatt, France



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Module Description
Manufacturer: Photowatt, France

Mechanical

Dimensions
Module: 104.3 cm x 46.2 cm
Cell: 10.0 cm^2

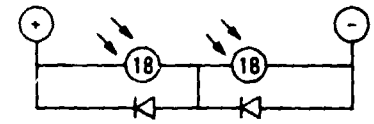
Packing factor: 0.75

Materials

Cells:	Semi XTL Silicon
Superstrate:	Tempered glass
Encapsulant:	PVB
Back cover:	Tempered glass
Edge seal:	Silicon rubber
Frame:	Aluminum

Electrical

CIRCUIT



Standard Conditions)

Power, max:	36.1 W
Voltage:	16.3 V
Current:	2.22 A
V_{oc}:	20.1 V
I_{sc}:	2.46 A
η, module:	7.5%
η, encapsulated cell:	10.0%

Module Description
Manufacturer: Siemens, West Germany

Mechanical

Dimensions
Module: 146.9 cm x 102 cm
Cell: 10.0 cm diameter

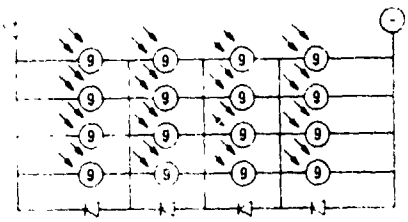
Packing factor: 0.75

Materials

Cells:	Single XTL Silicon
Superstrate:	Tempered glass
Encapsulant:	PVB
Back cover:	Tedlar/Al/Tedlar
Edge seal:	Foil tape/rubber
Frame:	Aluminum

Electrical

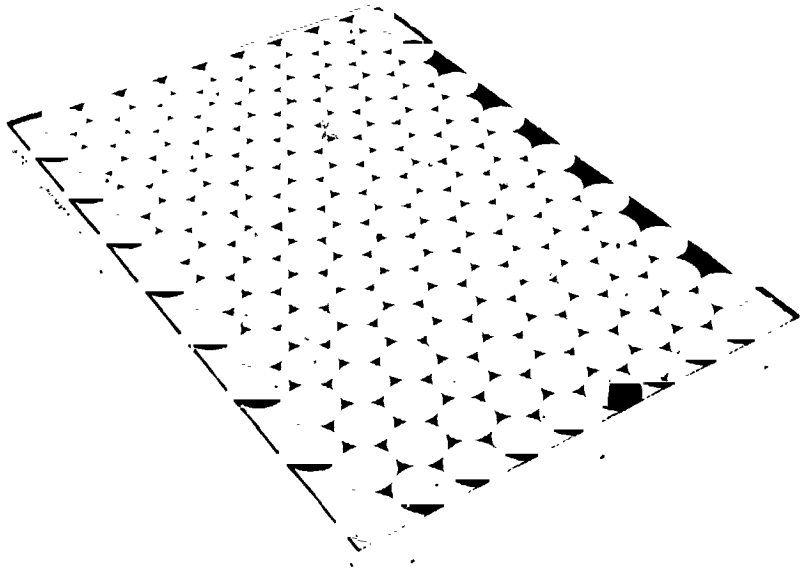
CIRCUIT



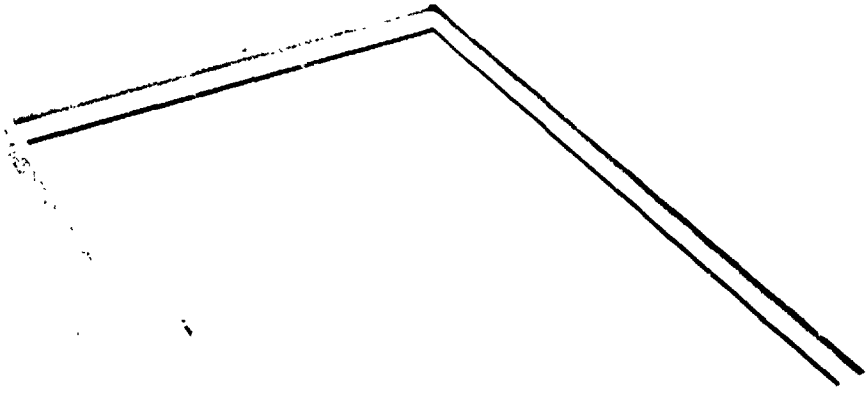
Sample Performance (Standard Conditions)

Power, max:	130.8 W
Voltage:	16.5 V
Current:	7.91 A
V_{oc}:	21.3 V
I_{sc}:	8.76 A
η, module:	8.7%
η, encapsulated cell:	11.6%

Photovoltaic Module (Top View)
Manufacturer: Siemens, West Germany



Photovoltaic Module (Bottom View)
Manufacturer: Siemens, West Germany



Qualification Test Record

Module Designs Tested	**12**
Number Passed	**6**
Number Failed	**6**

Failure Record

Test	Failed Designs	Failure Mode
T-50	1	Cracked interconnects. Power down
	1	Cracked cells. Power down
T-200	1	Encapsulant delamination
MI-10K	1	Cracked interconnects. Power down
Hot-Spot	2	Blistered Tedlar. Burn marks on Tedlar and encapsulant

Conclusions

- Most commercial modules use Block V technology
- Most commercial module designs do not pass the Block V Qualification Tests at the first attempt. (The Project phaseout plan precluded correction of defects and repetition of tests for the designs that failed)
- Semi-crystalline cell modules with one bypass diode per 36 series cells may pass the Hot-Spot test, but cell temperatures reach 150°C
- Although the precise cause of the cell cracks that caused power degradation was not determined, it seems clear that excess degradation would not have occurred if Block V (failure tolerant) cell/interconnect designs had been used
- It could not be determined whether the interconnect failures were caused by hitherto unexpected causes; failure analysis was terminated because of funding limitations
- The Block V Qualification Tests have again demonstrated their effective role in the development of reliable modules